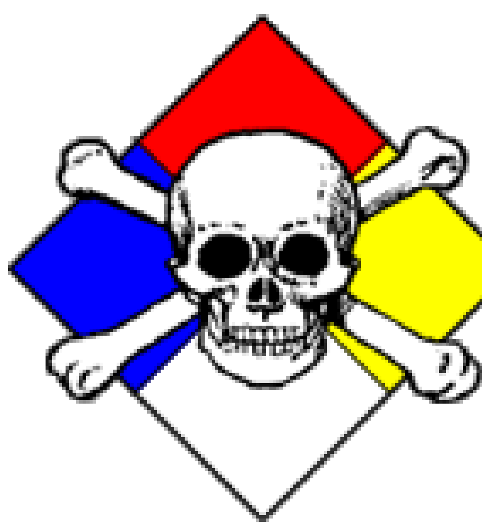
Disaster Site Worker Safety

Module 6

Military and Industrial Chemical Agents



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Overview

This module will cover selected chemical agents with regard to terms, definitions, and characteristics that will help a worker recognize the signs and symptoms of exposure and demonstrate the ability to forecast a downwind hazard that may impact their safety as well as the safety of others and the community.

Objectives

At the conclusion of this module, the participant will be able to:

- Identify some indicators of a chemical attack.
- Identify the five classes of military chemical agents.
- List the symptoms of exposure for selected chemical agents.

Introduction

Though there are more than 100 known types of chemical warfare agents, only a small number have actually been used in warfare. Even those agents that were used in combat were not used very much at all. In fact, World War I represents the only large-scale use of chemical agents.

International terrorism has been a global issue and threat for many years. Unfortunately, the 1995 incident in the Tokyo subway system involving the release of the nerve agent sarin placed an entirely new and foreboding specter on this threat. For the first time, a chemical agent was used for terrorism in a major metropolitan area.

The use of the nerve agent sarin in the Tokyo subway should have caused a major concern as a new and alarming dimension was added to the terrorist threat. With the terrorist use of sarin, a dangerous threshold was crossed. Chemical agents are no longer the exclusive property of military forces. The use of a military chemical agent signified the introduction of weapons of mass destruction into the terrorists' arsenals.

Before response personnel can hope to be effective at the scene of a chemical agent incident, they must be aware of the nature and characteristics of chemical agents. This awareness is essential for self-protection as well as for providing the capability to render aid and assistance to those affected.

The traditional view of weapons of mass destruction (WMD) brings to mind images of mushroom clouds obscuring the horizon. With the proliferation of improvised high explosive, chemical, biological, radiological, and nuclear devices, America has moved into an era where WMD are no longer limited to the militaries of superpower nations. Often called the “poor man’s” weapons of mass destruction, these improvised devices have become relatively easy to produce, hide, and utilize.

Until September 11, 2001, terrorists operating within the United States were long thought to be unlikely to use the sophisticated CBRNE agents designed for battlefield use. Instead, terrorists would probably use an explosive weapon, toxin, or pathogen that could be easily acquired, that would be easily employed, and that would be psychologically effective against mass populations.

Although there has been no specific confirmed use of toxic chemicals by foreign terrorists within the U.S., investigation has revealed that foreign terrorists had shown special interest in crop dusting aircraft and aircraft capabilities many months before the attacks in New York and Washington. This interest could indicate that dissemination of a CBRNE agent is a future possibility.

Chemical Warfare Agents and Terrorism

Chemical agents, in the context of terrorism, are combinations of chemicals that yield a toxic (i.e., poisonous) effect upon exposure. That is, they are designed to kill, sicken, or harm people when they are released. There are, of course, a multitude of chemicals; only a relative few are used as chemical agents in weapons of terrorism.

Chemical agents produce their effects as a result of chemistry rather than through the physical effects (e.g., blast, fragments, projectiles, heat) of conventional weapons, although when dispersed by means of an explosive device, both kinds of effects may occur. Inhalation of or contact with volatile chemicals can present a major danger of mass casualties and mass fatalities. The main differences between industrial chemical accidents and chemical terrorist incidents may be intent and magnitude.

Chemical Attack

Chemical incidents are likely to be overt (and in some instances easily identifiable) events. Chemical incidents are characterized by the rapid onset of medical symptoms (minutes to hours) and easily observed signatures (colored residue, dead foliage, pungent odor, dead insects, and animals). Dispersion methods may be as simple as opening a container or using conventional (garden) spray devices or as elaborate as detonating an improvised energetic/explosive device (IED).

A chemical terrorist event is likely to be discovered in one of two ways:

(1) The local discovery of the environmental release or exposure incident.

(2) The diagnosis of the resultant patient cases.

Some chemical agents produce delayed effects and some produce immediate effects, so considerable damage may have occurred by the

time the incident is detected and the cause identified. Indicators of a possible chemical terrorist incident are listed in the following table.

Chemical Attack Indicators

• **Mass casualties/mass fatalities**: Unusual numbers of sick or dying people with symptoms such as nausea, disorientation, difficulty breathing, convulsions, localized sweating, red eyes, red, or blistered skin.
• **Pattern of casualties/mass fatalities**: Casualties/fatalities distributed downwind (if outdoors). Casualties/fatalities grouped within a confined area (e.g., that shares an air ventilation system) if indoors.
• **Unexplained odors**: Unusual smells (e.g., fruity, flowery, sharp/pungent, garlic/horseradish-like, bitter almonds/peach kernels, new mown hay) that are out of character with the surroundings.
• **Dead animals/birds/fish**: Numerous dead animals (wild and domestic, small and large), birds, and fish in the same area.
• **Lack of insect life**: Normal insect activity (ground, air, and/or water) missing.
• **Different looking areas:** Trees, shrubs, bushes, food crops, and/or lawns that are dead, discolored, or withered in the absence of drought conditions.
• **Unusual fogs, clouds, mists, liquids**: Numerous surfaces with oily droplets or film when there has been no recent rain. Low-lying cloud/fog-like condition that is not consistent with its surroundings. Pools of liquid with unusual/unidentified source.
• **Abandoned spraying devices**.
• **Unusual metal debris**: Unexplained bomb/munitions-like material, especially if it contains a liquid.
• **An explosion.**

Classes of Chemicals

Chemical agents are classified according to their effects being either toxic or incapacitating. To help minimize miscommunication and misunderstanding when interacting with federal agencies, military classifications are often used. Knowledge and understanding of the special vocabulary used in response promotes an ease of communication within the interacting disciplines and agencies.

Chemical agents can be broadly grouped into three categories:

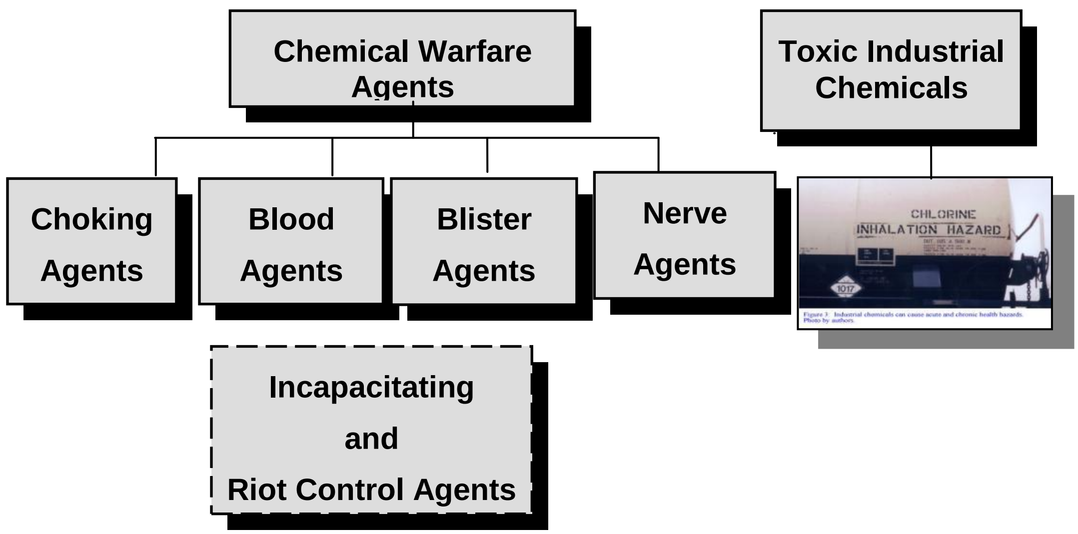
- *Casualty agents*: Agents intended to produce casualties (dead and injured people). They include nerve agents, blister agents, choking agents, and blood agents.
- *Irritant agents*: Agents that produce unpleasant sensations meant to harass or temporarily incapacitate victims (also called riot control agents). These agents include vomiting agents and tearing agents.

- *Psychochemicals*: Agents that produce changes in mental function, such as hallucinations or general confusion, also meant to temporarily incapacitate victims. Examples include LSD and BZ.

These categories can be further divided according to their primary effect on the human body. The chemical agents most often identified as potential weapons of terrorism are grouped within the following types:

- Nerve agents
- Blister agents
- Choking agents
- Blood agents
- Irritating agents

In addition, a few chemical agents are classified as incapacitants (this term sometimes includes both irritants and psychochemicals).



Nerve Agents

There are four significant military agents: tabun (GA), sarin (GB), soman (GD), and VX; these nerve agents are some of the most toxic chemicals known. They are hazardous in both their liquid and vapor states and can cause death within minutes of exposure. Nerve agents interrupt the normal functioning of nerve systems causing a variety of lethal effects.

Symptoms of Exposure		
Central Nervous System	**Autonomic Nervous System**	**Neuromuscular**
Respiratory arrest	Sweating	Weakness
Disorientation	Diarrhea	Trembling
Slurred speech	Nausea	Paralysis
Depression	Abdominal pain	Respiratory failure
Respiratory depression	Vomiting	
Headache	Reduced vision	
Convulsions	Pinpointed pupils	
Coma	Drooling	

Although nerve agents are not as readily available as the choking agents, they are much more toxic, and some are not difficult to produce.

Nerve Agent Characteristics

The common nerve agents are basically the same compounds originally synthesized in the 1930s by the Germans. There are two major classes of nerve agents. They are known as the G-series agents and the V-series agents. Most chemical agents are commonly designated by one or two-letter symbols. The first letter represents the type, group, or the developer, and the second letter represents a specific agent within the type or group. Accordingly, the common nerve agents are designated GA, GB, GO, and VX. The "G" stands for German and the A, B, and O signify the specific chemical. The common names for the G-agents, sarin, soman and tabun, are from part of the name of the scientist who developed each type.

The letter “V” represents another class of nerve agents. The most common agent in this group is VX. For VX, the "V" stands for venom; the "X" originates from a series of chemicals originally synthesized to be used as insecticides. VX has no common name.

Each of these agents is extremely fast acting, with victims exhibiting symptoms within seconds to a few minutes after exposure. The G agents are generally volatile and will evaporate, depending on concentration, in one to two days. These agents are generally considered non-persistent and present both inhalation

and skin contact threats.

VX has a low volatility and will evaporate about as quickly as motor oil; it is considered a persistent agent. Because of its low volatility, it is primarily a skin contact threat. However, if it were disseminated in aerosol form, it would also be an inhalation threat.

Like choking agents, nerve agents are heavier than air. When pure, the G agents are both colorless and odorless; however, if they contain impurities, GA and GB may have a slight fruity odor, and GD may smell like camphor. VX is odorless when pure. However, VX is normally not found in a pure state. In its impure state, VX may have a slight yellow color (light-weight motor oil) and will usually smell like sulfur.

Protection from these agents requires full respiratory and skin protection. Fire service bunker gear, properly worn, will provide some limited protection, but for operations in the hot zone, Level A protection is vital. For those who are contaminated, antidotes are available (atropine and 2-Pam chloride injections). Decontamination will work if the agent is quickly removed from skin. Flushing with water will work, but 0.5 percent bleach solutions are better.

Nerve agents are specific organophosphorus compounds considered to be the most dangerous of the chemical warfare agents. Similar physiological effects are produced by carbamates and other organophosphate-based pesticides. However, nerve agents are 100 to 500 times more potent than these other compounds.

The common nerve agents are listed below:

Common Name	Abbreviation	CAS #	NFPA 704	UN ID#	Hazard Class
Tabun	GA	77-81-6	4,2,1	2810	6.1
Sarin	GB	107-44-8	4,1,1	2810	6.1
Soman	GD	96-64-0	4,1,1	2810	6.1
V agent	VX	50782-69-9	4,1,1	2810	6.1

When the nerve agents GA, GB, GD, and VX enter the environment, the following occurs:

- **Air release**: GA, GB, GD, and VX will be broken down by compounds that are found in the air, but they may persist in air for a few days before being broken down.

- **Water release**: GA, GB, GD, and VX will be broken down in water quickly, but small amounts may evaporate.
- **Soil release**: GA, GB, GD, and VX will be broken down in moist soil quickly. Small amounts may evaporate into air or travel below the soil surface and contaminate groundwater.
- GA, GB, GD, and VX do not accumulate in the food chain.

Nerve Agent Properties

Nerve agents are liquids at ambient conditions. They are clear, colorless, and tasteless. The G agents are reported to have a slightly fruity odor; the V agents are said to be odorless. GA, GB, and GO are volatile compounds. GB is the most volatile. Although they are somewhat less volatile than water, all present a vapor hazard under temperate conditions. VX is oily with low volatility. A large surface area or widely dispersed droplets can, especially under high temperature conditions, present an inhalation hazard. All nerve agents penetrate the skin rapidly as well. Inhalation of vapors or aerosols is especially dangerous.

Exposure to these agents causes a disruption of nerve impulse transmissions by reacting with the enzyme acetylcholinesterase. Exposure to even minute quantities may be rapidly fatal.

Nerve Agent Detection

Detection clues for nerve agents are limited because they resemble water or light oil without any characteristic odor. Large inventories of these materials are usually found only at secure military laboratories or ammunition depots. There are a few private laboratories that conduct chemical agent testing for the government in the United States. Awareness of the location of such a facility in your area is essential. Consequently, any incident in or around a known facility should be suspect. Transportation of nerve agents in bulk in the United States has been very limited, and such transports are accompanied by members of the U.S. Army Technical Escort Unit. Clandestine activities that may involve nerve agent production may be evident by the presence of unusual chemicals, laboratory glassware as well as underground "cook books," military manuals, or chemical textbooks.

Clandestine Labs

Discovery of a clandestine laboratory or storage site containing unusual chemicals in an unexpected or unlikely place may be indicative of an intention to synthesize chemical agents. Chemicals used to synthesize other chemicals are called precursors. The precursors for nerve agents are not generally found in bulk in commercial shipments nor are they usually associated with clandestine drug laboratories.

Possible nerve agent precursors are listed below:

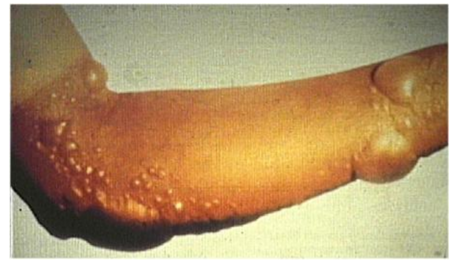
Ammonium bifluoride	Diethyl ethylphosphonate	Diethyl, N-dimethyl	Phosphoramidate
Diethylphosphite	Diisopropylamine	Dimethylamine	Dimethyl methylphosphonate
Dimethyl ethylphosphonate	Ethylphosphonous dichloride	Ethylphosphonous difluoride	Ethylphosphonyl difluoride
Hydrogen fluoride	Ethylphosphonyl dichloride	Methylphosphonyl difluoride	Methylphosphonyl dichloride
N, N -Di isopropyl-(beta)-aminoethanol	N, N-Di isopropyl-aminoethanethiol	N,N-Di isopropyl-(beta)-aminoethyl Chloride	Phosphorus oxychloride
Phosphorus pentachloride	Phosphorus pentasulfide	Phosphorus trichloride	Pinacolone
Pinacolyl alcohol	Potassium bifluoride	Potassium cyanide	Potassium fluoride
Sodium cyanide	Sodium fluoride	Thionyl chloride	

Nerve Agent Outward Warning Signs

Outward warning signs will generally be the first clue of a release of nerve agent. The most significant sign will be the rapid onset, within minutes, of similar symptoms in a large group of people. Except for dermal exposure, pinpointed pupils (miosis) are the best symptomatic indication of nerve agent use. Because the nerve agents are so lethal, mass fatalities can occur without other signs of trauma. Other outward warning signs of a nerve agent release are:

- Explosions that seem only to destroy a package or bomb device.
- Abandoned spray devices.
- Numerous dead animals, fish, and birds.
- Lack of insect life.
- Mass casualties without obvious trauma.
- Definite pattern of casualties and common symptoms.
- Civilian panic in potential target areas (government buildings, public assemblies, subway system, etc.).

Blister Agents



Blister agents are heavy oily liquids. In the pure state they are colorless and nearly odorless, but in the impure state they are dark-colored and have an odor strongly suggesting mustard, onion, or garlic.

These agents are extremely toxic, although far less lethal than nerve agents. A few drops of mustard on the skin can cause severe injury, and three grams absorbed through the skin can be fatal.

Symptoms of exposure may not appear for minutes, hours, or days. Symptoms include:

- Eyes: Exposure time until symptoms appear, one-and-a-half to 12 hours (except for Lewisite where there is eye irritation early on). Reddening, congestion, tears, burning, and gritty feeling in the eyes. In more severe cases; marked swelling of the eyelids, severe pain, and spasm of the eyelids.
- Skin: Exposure time until symptoms appear, 1 to 12 hours. Initially, mild itching only followed by redness, tenderness, and burning pain in the affected area. Later, burns appear, some with large fluid-filled blisters. The blisters appear particularly in the groin and armpit where the skin is warm and moist.
- Respiratory system: Exposure time until symptoms appear, 2 to 12 hours. Burning sensation in the throat and nose, hoarseness, profusely runny nose, severe cough, severe shortness of breath.
- Digestive system: Exposure time until symptoms appear, 2 to 3 hours. Abdominal pain, nausea, blood-stained vomiting, and bloody diarrhea. Detection clues for blister agents are limited. These materials are usually found only at secure military installations, and any incident in or around this type of facility may be suspect.

Generally, these materials are not transported except in very small amounts. The presence of unusual chemicals in unlikely places, underground "cook books," military or chemical books, and even a clandestine laboratory may also be clues.

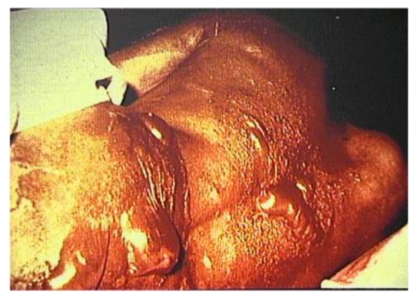
Chemicals used to prepare blister agents may be discovered in storage, shipment, or in a clandestine laboratory. Precursors are:

Thiodiglycol	Thionyl chloride	2 -Chloroethanol
Arsenic trichloride	Trithanolamine	Sodium sulfide
Hydrochloric acid		

Warning Signs

Outward warning signs will generally be the first clue of a release of blister agents. Signs may not be as immediately evident as would be the case for nerve agents. Blisters take hours to days to develop. Complaints of eye and respiratory irritation along with the reports of the characteristic garlic-like odor would be the initial signs. Similar symptoms experienced by a large number of people as well as the following may indicate a blister agent release:

- Explosions that dispense liquids, mists, or gas
- Explosions that seem only to destroy a package or bomb device
- Unscheduled and unusual spray being disseminated
- Abandoned spray devices
- Mass casualties without obvious trauma
- Definite pattern of casualties and common symptoms
- Civilian panic in potential target areas (government buildings, public assemblies, subway system, etc.)



Vesicants (blister agents) attack the skin, eyes, respiratory system, and gastro-intestinal tract. Skin penetration is, at first, painless and unnoticed. When erythema (redness of skin) appears, it will be accompanied by severe itching and blisters. Eye penetration also occurs painlessly. Lacrimation (tearing) and inflammatory reactions begin to appear one to several hours after exposure bringing pain, extreme light sensitivity, and spasmodic winking.

Four to six hours after exposure, the respiratory system will begin to exhibit symptoms that include nasal secretions, burning pain, hoarseness, progressive coughing, loss of voice, and difficulty breathing. Gastrointestinal effects result in destruction of mucus membranes. Symptoms include pain, bloody diarrhea, nausea, vomiting, and extreme weakness. Shock is possible. Their effect upon exposed tissue is somewhat similar to that of a corrosive chemical such as lye or a strong acid.

Types of Blister Agents

There are a number of blister agents:

- Mustards (H) (referred to as mustard agents)
- Lewisite (L)
- Phosgene oxime (CX)

Of this group, mustard (H) is the most likely to be used as it is the easiest to produce. These agents are normally disseminated as liquids. Under

normal temperatures, they have low volatility, so they are persistent. Mustard freezes at around 56 to 58°F, so it probably would not be used outdoors during cold periods. Mustard has a definite garlic-like odor and appears as an oily liquid. It is primarily designed for liquid skin contact; however, the vapors are extremely dangerous in the lungs and in sufficient concentration, the vapors will cause blistering of the skin.

Although the agents attack immediately upon contact, people will not immediately feel pain with the mustards. Visible effects may take from six to 24 hours to appear; thus, one may not immediately realize that he or she has been contaminated. The agent is absorbed rapidly into the skin. A few hours after exposure, one will notice a reddening of the skin where the contamination occurred and later the formation of a large, well defined blister, hence the name.

For the purpose of this module, the only major difference between the mustards (H) and lewisite (L) or phosgene oxime (CX) is that L and CX cause immediate pain upon contact with the skin. Blister agents affect both the respiratory tract and the skin; therefore, full respiratory and skin protection is essential. First aid involves getting the agent off any exposed skin as quickly as possible and then flushing with water. Decontamination is essentially the same, removal followed by flushing with water. A 0.5 percent bleach and water solution will aid in skin decontamination. However, information published in the *Journal of the American Medical Association* (JAMA) has begun to question whether soap and water may be just as effective in decontaminating the skin.

NOTE: Exercise caution anytime bleach of any strength is applied to skin. Bleach is not indicated for people with skin problems, open wounds, or the very young and elderly.

Sulfur Mustard (HD)

Sulfur mustard is the best known of the mustard agents. Like many of the other mustard agents, it is most likely to be used both to produce and to force enemy troops to wear protective equipment causing them to fight less efficiently. Also, like other mustard agents, sulfur mustard can contaminate anything it touches for long periods of time. In its pure state, it is colorless and almost odorless. When odor is present, it smells like rotten onions or mustard. Sulfur mustard, like other chemical weapons, can be thickened by adding a polymer. Sulfur mustard and other mustards are able to penetrate cell membranes in tissues and many other materials (wood, rubber, plants, etc.).

Because sulfur mustard is a "bifunctional alkylating agent," it contains two reactive chloroethyl functions. The key to how sulfur mustard works is in its ability to covalently bond to other substances. The chlorine atoms in sulfur mustard split off the ethyl group and attach to a reactive sulphonium ion. This ion can in turn bind to a wide variety of biological molecules, such as nucleic acids, proteins, and nucleotides. Sulfur mustard can create cross-links between nucleotides of DNA and RNA, thus inhibiting DNA and RNA replication. Because sulfur mustard is a bifunctional agent, it can also form links between molecules. By means of alkylation, sulfur mustard destroys large amounts of living tissue within an individual. Overall sulfur mustard and other mustards cause massive cellular mutations within an individual.

Sulfur mustard attacks the skin, eyes, lungs, and gastro-intestinal tract of any individual who is exposed to it. Of course, these are not the only parts of the body that can be affected by sulfur mustard. Internal organs, mainly the blood-generating organs, can also be badly damaged. Symptoms of sulfur mustard do not show up until two to 24 hours after the initial exposure occurs. But by the time the symptoms begin to occur, the damage has already been done.

The symptoms of sulfur mustard typify those of all of the other mustards, mostly because they extend over a wide range. The symptoms of a mild poisoning by sulfur mustard are aching eyes (massive amount of tearing), inflammation of the skin, irritation of the mucus membrane, coughing, sneezing, and hoarseness. Overall, mild poisonings do not warrant medical treatment. However, unlike mild poisonings, exposures to large amounts of sulfur mustard are incapacitating and require immediate medical attention. Such injuries that can occur are loss of sight, nausea, severe respiration difficulty, vomiting, blistering of the skin, and diarrhea.

The liquid state of sulfur mustard causes severe injuries, whereas exposure to sulfur mustard in the gas state usually causes mild injuries. Depending on the level of exposure, mustard agents will cause different levels of skin inflammation, ranging from a little irritation to a skin necrosis that is so comprehensive that no blisters occur.

Nitrogen Mustards (HN)

All of the nitrogen mustards are liquids that are dark in color and oily. These mustards are much more dangerous than sulfur mustard, but like sulfur mustard, they are derivatives of ammonia. The nitrogen mustard inflicts the most damage on the lower intestinal tract. The most toxic and most volatile of the three nitrogen mustards is HN-2, but HN-3 is used more because of its stability. Other than the fact that it is slightly more dangerous than sulfur mustard, everything else about the nitrogen mustard is the same.

Phosgene Oxime (CX)

Phosgene oxime is found in both liquid and solid form. The only difference between this and the other mustards is that its "typical mustard agent effects" occur immediately after exposure.

Lewisite (L)

Lewisite is a dark oily liquid that smells like geraniums. Lewisite is a quick-acting blistering agent that causes more pronounced blistering than most blistering agents. Once inside the body, it causes systemic destruction. Another major difference between this and other mustards is that it produces low blood pressure, lung swelling, and bowel troubles. An exposure to a high concentration of Lewisite can kill in ten minutes, whereas a low exposure can cause symptoms to occur in 30 minutes. Lewisite is a mustard agent that is most often mixed with other chemical weapons agents to produce an extreme effect on an individual.

Phenyldichloroarsine (PD)

Phenyldichloroarsine has no odor or color and is most often in a liquid state. Beside the fact that its is slightly less effective than sulfur mustard and that it makes use of a gas mask more difficult, all other characteristics of it are like that of sulfur mustard.

Ethyldichloroarsine (ED)

Ethyldichloroarsine causes an immediate irritating effect to any individual exposed to it. Other than this fact and the fact that it is less persistent than sulfur mustard, it is like sulfur mustard in every other way.

Blood Agents

Cyanides or blood agents include common industrial chemicals such as potassium cyanide, which can cause rapid respiratory arrest and death. There are two blood agents: hydrogen cyanide (AC) and cyanogen chloride (CK). Both are commercially available and used in various manufacturing processes. Both would probably be made into weapons or packaged as liquids. Once released into the atmosphere, they will rapidly vaporize, becoming true gases at normal temperatures.

Hydrogen cyanide (AC) is lighter than air and, unlike the other agents, will rise; cyanogen chloride (CK), conversely, is heavier than air. Both are non-persistent and smell like bitter almonds (peach pits). If hydrogen cyanide (AC) were used, sheltering in place would require people to remain on ground floors because hydrogen cyanide (AC) will evaporate and rise rapidly; however, cyanogen chloride (CK) is heavier than air and sheltering-in-place considerations for it are the same as for phosgene and chlorine, uphill or upstairs.

Both are inhalation threat agents and, once inhaled, will take effect immediately. First, victims will gasp for air (they may appear to be gulping air), froth or vomit, and then lose consciousness and die. (This

process will occur very rapidly.) First aid is a matter of leaving the contaminated area. Decontamination is best accomplished by aeration.

Blood agents produce casualties by interfering with the blood's ability to transfer oxygen to the cells, which can lead to death by asphyxiation. Blood-agent poisoning causes rapid death when the exposure is in high concentrations. Small concentrations cause respiratory distress, vomiting, diarrhea, vertigo, and headache. Large numbers of casualties displaying these common symptoms and reporting odors of peach blossoms or bitter almond indicate a possible blood agent release.

Blood agents are liquids under pressure. The presence of lecture bottles and gas cylinders is a possible clue. Most blood agents are derivatives of cyanide compounds. The discovery of packages of cyanide salts and acids that are precursors for blood agents may also be considered clues.

Common Name	Abbreviation	CAS #	NFPA 704	UN ID#	Hazard Class
Hydrogen cyanide	AC	74-90-8	4,4,2	1051	6.1
Cyanogen chloride	CK	506-77-4	4,4,2	1589	2.3

These agents are common industrial chemicals. Information on these agents should be readily available from most technical reference sources.

Choking Agents

Pulmonary or choking agents include common industrial chemicals such as chlorine, which can cause eye and airway irritation, shortness of breath, chest tightness, and delayed pulmonary edema (fluid in the lungs). There are two choking agents: phosgene (CG) and chlorine (Cl_2). Both of these agents are commercially available and could be obtained and used by terrorists. Because they have low boiling points, they will rapidly become a gas when released under normal conditions. This also makes them non-persistent, meaning that they will not remain in an area for any length of time.

Because choking agents are heavier than air, they will settle into low places in the surrounding terrain. Subways, sewers, and manholes would be likely concentration areas if phosgene or chlorine were used. Therefore, evacuation to higher floors in buildings and evacuations of subways would be appropriate.

Although some agents have distinct odors (phosgene (CG) smells much like newly mown hay, and chlorine (Cl_2) smells like a swimming pool), smell is not a good means of detection because, once inhaled, these agents are immediately irritating to the respiratory tract. Victims may cough or appear to be choking, but it could be two to three hours after

exposure before the victims begin to show serious symptoms. Exposure to a high concentration of chlorine vapor can react with body moisture causing serious burns and degradation to clothing. Self-aid is simply a matter of getting oneself out of the contaminated area and decontaminating by flushing with water and aeration.

Choking agents are irritating to the throat and lungs. When the agent comes in contact with the fluids in the lining of the throat and lungs, it hydrolyzes to hydrochloric acid (HCl), which in turn burns the throat and lung walls and causes the lungs to secrete fluid that collects in the lungs. As the air sacs in the lungs fill with fluid, they prevent oxygen transfer to the bloodstream causing death due to oxygen deficiency.

This process is frequently referred to as “dry land drowning.” Because choking agents target the respiratory system, one will need good respiratory protection such as the self-contained breathing apparatus (SCBA). There is no absorption through the skin; however, if liquid does come into contact with the skin, it will burn and should be flushed off immediately.

Choking agents produce casualties by severely stressing the respiratory system tissue. Severe distress produces profuse edema, which can result in death by asphyxiation that resembles drowning.

These agents are common industrial chemicals. Information on these agents should be readily available from most technical reference sources.

Common Name	Abbreviation	CAS #	NFPA 704	UN ID#	Hazard Class
Chlorine	Cl	7782-50-5	3,0,0	1017	2.3
Phosgene	CG	75-44-5	4,0,0	1076	2.3

Incapacitating Agents (Irritating Agents)

Incapacitating agents also called irritants, lachrymators, and tear gas, produce discomfort and eye closure that render the receiver temporarily incapable of fighting or resisting. Exposure is through inhalation and absorption of small particles suspended in the air. Despite the common names, these are not gases; they are micro-pulverized solids. Incapacitating agents cause pain, burning, or discomfort to exposed mucous membranes and skin; these effects occur within seconds of exposure but seldom persist more than a few minutes after exposure has ended.

These agents are relatively easy to obtain. If used in conjunction with any of the agents already discussed, it or they could easily mask the use of a more serious agent. Many of these agents are commercially available as self-protection devices.

First aid and decontamination for these types of agents are relatively simply. Move the victims into an uncontaminated area and face them into the wind. In extreme cases, one should apply large amounts of water and change the victims' clothing.

These agents are also known as riot control agents or tear gas. They cause respiratory distress and copious tearing that may incapacitate a casualty. They are generally non-lethal but under certain conditions can act as an asphyxiant.

Another common compound that produces effects similar to tear gas is pepper spray. The active ingredient in pepper spray is capsicum. Capsicum is a natural organic compound extracted from hot peppers. The frequency of incidents involving these agents appears to be on the increase in schools and fast food restaurants as the "keychain" personnel defense devices are available at retail stores almost everywhere. There are several manufacturers, and the devices may contain either a single agent or a mixture. Some devices contain dyes to visually mark a sprayed assailant.

The common irritating agents:

- Chloropicrin
- MACE
- Tear gas
- Capsicum/pepper spray
- Dibenzoxazepine

Outward Warning Signs

Outward warning signs will generally be the first clue of a release of irritating agents. Signs will include casualties complaining of burning and irritation of the eyes and throat. In severe exposures or when direct contact with the liquid occurs, complaints of burning skin as well as abdominal pain may also be present. Exposure to these agents is accompanied by tearing, coughing, choking, difficulty breathing, nausea, and vomiting. Additional signs and symptoms may include:

- A characteristic peppery odor in the area of the event.
- A characteristic peppery odor on the clothing of persons exposed.
- Reports of tear gas-like odor from those exposed.
- Identification of tear gas munitions used by either military or police.
- Identification of discharged personal protection devices.
- Dye stains near the site of the suspected release.
- Brownish-colored stains on objects near the site of the suspected release.

The effects of these agents are temporary, although casualties must be monitored should the irritant trigger a secondary medical problem such as an asthma attack or other respiratory problem. Infants and the elderly will usually exhibit the most severe symptoms and secondary medical problems.

Detection

Detection clues for the irritating agents are usually the characteristic odors reported by those exhibiting symptoms and recognition of the dispensing devices. Irritating agents are dispensed from burning or bursting grenades in the form of micro-pulverized powders. They can also be dispersed by either a dry sprayer or in a liquid pressure spray can. Personal defense devices are low concentrations of agents dispensed in a carrier solution from a small spray device.

Routes of Exposure

There are five possible routes of exposure for chemical agents: absorption, inhalation, dermal contact, ingestion, and intravenous entry.

- *Absorption* (mucous membranes)
    - Many chemical agents can be absorbed through mucous membranes that line the mouth, nose, and throat.
- *Inhalation* (lungs)
    - Chemical agents in gas, vapor, or aerosolized form can be inhaled. Once in the lungs, the agent can damage the lungs and interfere with breathing or enter the circulation.
- *Dermal Contact* (skin)
    - Some agents can be absorbed through the skin and eyes, into the circulatory system.
- *Ingestion* (by mouth)
    - The agent can be ingested if a victim eats contaminated food or drinks contaminated water.
- *Intravenous Entry* (bloodstream)
    - If a victim gets cut by a contaminated article (e.g., a piece of shrapnel, flying glass), the chemical agent is injected directly into the circulatory system.

Advantages for Use of Chemical Agents as Weapons

A number of factors favor the use of chemical weapons by terrorists:

- *Widespread availability*: The ease with which ingredients can be inexpensively obtained and the ease with which the agents can be synthesized without highly specialized scientific knowledge, puts

chemical weapon production within reach for terrorist organizations.

- *High level of toxicity*: A small amount can do considerable damage. This fact eases problems associated with production, storage, transport, security, and placement.
- *Difficulty of detection*: Chemical agents are difficult to detect by conventional antiterrorism countermeasures (e.g., sensor systems).
- *Time lag:* The delayed effects of some agents make it easier for perpetrators to escape before the incident is recognized and responded to.
- *Anonymity:* Because they can be synthesized relatively simply from commercially available ingredients, chemical agents cannot be traced back to a particular "strain" or origin in the way some biological agents can.
- *Societal disruption*: The degree of terror associated with a chemical or biological terrorist attack has the potential for seriously disrupting the normal workings of society among the target population. The potential economic toll on society for response, treatment, recovery, investigation, countermeasures, and other aspects of the aftermath could be astronomical.

Factors Point toward Increased Future Usage

Authorities in terrorism cite the following factors as pointing toward the likelihood of future use of chemical and biological agents by terrorists:

- Increased security against traditional types of terrorist attacks.
- Public indifference to traditional forms of terrorism, requiring more spectacular acts to gain attention.
- Recent increases in high-casualty, less discriminate attacks.
- Growth of state-sponsored terrorism.
- Worldwide proliferation of chemical and biological weaponry.
- Increased inter-ethnic and religiously inspired violence.
- Decrease in humanitarian inhibitions.
- Availability of materials and expertise from the former Soviet Union, its allies, and the growth of organized crime in those countries.

Relative Lethality: Chemical Agents in Relation to Chlorine

This is a representation of the approximate lethality of the agents in relation to chlorine. If chlorine is used as a baseline, then:

- Cyanogen chloride is twice as toxic.

- Phosgene is six times more toxic.
- Hydrogen cyanide is seven times more toxic.
- Mustard is 13 times more toxic.
- Sarin is 200 times more toxic.
- VX is 600 times more toxic.

For skin toxicity, 1 to 2 grams of mustard or sarin or 10 milligrams of VX are required. Skin toxicity for VX requires a quantity that is 100 to 200 times less than either mustard or sarin.

Chemical Downwind Hazard Predictions

A weapon of mass destruction CBRNE device, when activated, may release a cloud of material, which will then move with the wind. Depending on the concentration of the agent in the cloud, people downwind of the release can become victims.

The purpose of the downwind hazard analysis is to warn downwind personnel, prevent people from stumbling into the hazard, and make informed decisions about the allocation of critical resources to where they are needed most.

Eventually, the air to an extent that it no longer poses a hazard will dilute a toxic cloud. As in conventional Hazmat incidents, “Dilution is the solution.” The task may be to advise the Incident Commander (IC) on the downwind hazard using the techniques learned in this lesson.

A plume is a vaporous release that emanates from a toxic substance source. A cloud, in contrast, has left its source and moves (floats) away. Both plumes and clouds are analyzed in the same manner for downwind predictions. Many factors affect the travel of a toxic plume or cloud.

Physical Properties That Affect Dissemination

In addition to the agent’s physical form (vapor, gas, aerosol, spray, liquid, solid), other physical properties of a particular chemical agent will affect its effectiveness as a weapon, the ways it can best be disseminated, and the severity of the effects it produces in victims.

The chart on the following pages provides a brief descriptor of the physical properties of these agents.

Physical Properties

Property	Description
Flow Characteristics	Dissolving solid and viscous (thick) liquids gives them better flow characteristics (that is, makes them flow more smoothly). The flow characteristics of an agent affect the ease with which it can be dispersed through an aerosol nozzle and whether it forms a fine mist that can remain airborne a long time (as opposed to merging into heavy droplets that fall quickly to the ground).
Corrosiveness	Some chemical agents are highly corrosive. For these agents, the production equipment, storage containers, and dissemination devices must be able to withstand the corrosive effects of the agent.
Volatility	Volatility is the ease with which an agent forms a vapor as it evaporates. Because vapor clouds produced by toxic chemicals are hazardous, a highly volatile chemical agent might be an attractive choice for a terrorist weapon. (A volatile agent that is lighter than air; e.g., hydrogen cyanide) would quickly dissipate outdoors and make it less effective, but it would be effective in confined spaces.) Volatility is related to several other factors: • Volatility relates to temperature: the higher the temperature, the higher the volatility. • Volatility is commonly expressed as the equilibrium concentration of the material in the air ¾ the concentration that does not change over time for a given temperature. This concentration is stated as weight of agent per volume of atmosphere (e.g., mg/1 or mg/m3). The larger the equilibrium concentration, the more easily the agent evaporates. • Volatility is related to vapor pressure, expressed as units of pressure at a given temperature. The larger the vapor pressure, the easier the material becomes a vapor. • Volatility is inversely related to persistence: the higher the volatility, the lower the persistence.
Persistence	Persistence is the length of time an agent remains effective after delivery. However, persistence depends on environmental conditions, the agent used, and the amount used. For example, some agents are gone within a few hours in wet conditions. Others evaporate in the heat. Evaporation rates also differ with the type of surface on which the agent lies. Three levels of persistence have been described: non-persistent, semi-persistent, and persistent. These terms are variously defined and depend heavily on environmental conditions. • Non-persistent: Minutes to hours • Semi-persistent: Less than 12 hours • Persistent: More than 12 hours Persistence may also be expressed in terms of the speed at which the agent will evaporate relative to the speed at which water will evaporate at 15°C, sometimes known as an S value. For example, an agent with a persistence of 6 would evaporate 6 times faster than water at 15°. S values are useful primarily for comparisons. It may be possible to increase the persistence of an agent by mixing it with other more persistent agents or thickeners or by particulation (rendering it into powder form). **Most** persistent ⟶ **Least** persistent VX, Tabun, Mustard, Lewisite, Sarin, Hydrogen Cyanide, Cyanogen Chloride, Phosgene, Chlorine
Contamination Density	Contamination density is the amount of agent applied to a given area, measured in mass of agent per unit of area (e.g., grams per square meter).

<table>
<tr><th>Property</th><th>Description</th></tr>
<tr><td>Concentration</td><td>Concentration is the relative content of the chemical agent in the mixture or its strength. This property is described in several different ways.
Theoretical concentration is how much of the agent has been placed in a given volume (e.g., 5 grams per liter).
Effective concentration begins with amount of the agent and reduces that amount by how much is left in the container, absorbed in carpeting, etc. This is also referred to as true concentration, actual concentration, or real concentration.
Effective concentration is also used to mean the concentration needed to desired effect (e.g., “the effective concentration for producing 50 percent casualties in unprotected personnel”).</td></tr>
<tr><td>Toxicity</td><td>Toxicity is the relative severity of the illness or incapacitation cause by the agent. Common indicators of toxicity, expressed as a single number or a range, include:
ID50: Median incapacitating dose (the dose that will disable 50 percent of those exposed to it).
ICt50: Median incapacitating exposure (Ct=unchanged with time).
ECt50: Median exposure at which an effect is observed.
NOEL: The No-Observed-Effect Level (below this dose no effects are seen).
NOAEL: The No-Observed-Adverse-Effect Level (like NOEL, but used when good effects are possible).
LOEL: Lowest-Observed-Effect Level (lowest level at which an effect is observed).</td></tr>
<tr><td>Lethality</td><td>Lethality is the ease with which it causes death.

A measure of lethality is Lethal Dose for 50 Percent, or LD50. This is the size of the dose for an individual that will kill half of all the people receiving it. For chemical agents, LD50 is usually expressed as mass of the agent per kilogram of the victim’s body weight (e.g., mg/kg). The exposure route should be given along with LD50, because the effects of an agent may vary greatly depending on how the agent enters the body.

Another measure, used primarily for vapors, is the median lethal exposure, or LC50.

In this measure, exposure is derived from concentration of agent multiplied by time of exposure).

A common rule of thumb is to assume that a dose ten times the LD50 or LC50 will result in total loss of life among the exposed.</td></tr>
<tr><td>Rate of Action</td><td>Rate of action refers to how quickly symptoms appear after exposure. The rate of action depends on several factors, including the specific agent, its concentration, whether the victim is protected, and the individual’s characteristics. The following categories are used to classify rate of action, although they are only loosely defined:
Precipitous: Within a few minutes
Rapid: A few minutes to tens of minutes
Delayed: Ten minutes to several hours</td></tr>
</table>

Weather Is a Major Factor

Wind speed and direction, air stability (inversion, neutral, and lapse), temperature, precipitation, and humidity are factors that determine where

a plume or cloud travels and how long it poses a hazard. With wind speeds less than 6 mph, the cloud tends to disperse evenly in all directions (creating a circle around the release point). At wind speeds above 6 mph, the cloud tends to form a pear shape as it travels downwind. Precipitation can wash the agent out of the air but may cause a runoff problem. Because biological agents are destroyed by sunlight's UV radiation, a biological cloud will travel further downwind during darkness than during the day.

Air stability is important. On hot, sunny days ground-level air tends to rise, taking the toxic cloud with it. During evenings and overcast days, the ground air and cloud tend to stay low.

Meteorological Conditions and Other Factors

The effects of a chemical attack are affected by meteorological conditions and other environmental factors including:

- Temperature (air and ground).
- Humidity.
- Precipitation.
- Wind speed and direction.
- Surrounding or nearby buildings and terrain.

The table gives examples of the possible effects of these conditions and factors.

Condition/Factor	Possible Effects
Temperature	• Higher air temperatures may cause evaporation of aerosol particles, decreasing their size and improving their inhalability. • Ground temperature can either increase or decrease evaporation rates and persistence.
Humidity	• High relative humidity may enlarge aerosol particles, lessening their inhalability. • High humidity plus high temperature causes people to sweat more, and moisture intensifies the effects of mustard agents on skin.
Precipitation	• Light rain disperses and spreads chemical agents, causing faster evaporation. • Heavy rain dilutes and disperses chemical agents, allowing it to penetrate the ground more easily. It can also spread contamination to other areas. • Snow slows evaporation and increases persistence of contamination.

Condition/Factor	Possible Effects
Wind Speed and Direction	• Wind speed determines how fast a primary cloud moves. • Wind direction dictates which areas will be downwind of the release and subject to contamination. • High winds can disperse vapors, aerosols, and liquids rapidly, shrinking the contamination area and reducing exposure to the agent.
Buildings and Terrain	• Soil and surface type affect evaporation, absorption, persistence, and rate of vapor movement across the ground. • Forestation and hills can interfere with vapor movement and increase exposure in the area where the agent is trapped.

The Type of Agent and Quantity Is Also a Factor

Some liquid materials (GB for example) evaporate quickly and create a dense, short-lived hazard. Other agents (VX) evaporate very slowly and could create a low-density cloud of long duration. Naturally, the size and hazard of a cloud created from one liter of material is less than the hazard from a tank car of the same material.

Buildings and Terrain

The presence of buildings and terrain features (hills, valleys, trees, etc.) can have a major effect on wind direction and degree of air turbulence. This is evident in a city with tall buildings, where the wind can be moving in several different directions within a few blocks.

Dissemination Influences

Dissemination methods and parameters also influence cloud formation. A vapor from an evaporating liquid puddle will form a less dense vapor cloud than one from a pressurized spray.

Factors That May Pose Problems

There are several factors that can cause problems with predicting where a toxic cloud will go, how far it will travel, and how long it will remain a hazard. Knowledge of micro weather (ground level, incident site) is invaluable. Weather at the airport can be much different than it is at the incident site. Even if the micro weather at the site is known, the downwind area weather may not be known.

The quantity of the agent released will probably be unknown, unless the agent was released from a known quantity container such as a rail car, tank truck, or a fixed facility such as a tank farm (manufacturing facility). Even if the device has been recovered and an estimation of how much liquid was in it has been made, the purity will probably not be known. The

name of the agent may not even be known at first. For example, nerve agent tabun (GA) behaves much differently than nerve agent soman (GD), but field tests will probably not effectively distinguish between the two. Current computer models (ALOHA, D2PC, etc.) do not adequately model the effects of terrain and cities; they are based on assumptions and test data from flat, open plain dissemination.

Finally, by the time a prediction can be made, the cloud may be gone, carried downwind and diluted, or raised in the atmosphere above the point where it could harm people. This would be especially true in a small quantity "puff" event created by the release of a non-persistent agent (such as an AC/blood agent) that evaporates very quickly.

Since all predictions are based on many pieces of unfamiliar data, do not be deceived by the sophistication of a computer model. Remember that a downwind hazard prediction is only a prediction, not a fact.

What Can Be Done

Some assumptions can be made by using familiar methods to make a prediction. If ALOHA or CAMEO (or another applicable computer program) is available, it could be useful. If it is not, the simplified method in the Emergency Response Guidebook (ERG) is effective and could be reasonably accurate for the situation. The ERG was ideally designed for predicting the isolation and protection distances within the first 30 minutes after an incident.

Other Methods

Track 911 calls by plotting them on a map.

Track the location of victims by plotting them on a map.

Guide Book Method

Step 1: To use this method, one needs to know the material involved. Look up the material ID number from the blue pages. If the exact name of the agent is not known or its name is not there, use the agent class. For example, for nerve agents use ID 2810; for the blood agents use ID 1051; and for blister agents use ID 2810. Whenever multiple isolation and protection distances are shown for an agent class, use the greatest distances in the agent class for maximum protection.

Step 2: Look up the ID number in the green pages and read across to the initial isolate distance and protect distance.

Determine if the event is a small incident (less than 55 gallons) or a large incident (larger than 55 gallons), as defined by the Emergency Response Guidebook, and if it is day or night.

Step 3: The third step is, itself, comprised of three steps:

- On a map of the incident area, draw (to scale) a circle with the radius of the initial isolation distance, with its center at the center of the incident site.
- Mark which way the wind is blowing at the site.
- Then, through the center of this circle, place the upwind edge of a square box which is the protect distance on each side. This edge is perpendicular to the wind direction.

For practical purposes, the potential hazard area has been defined, and the toxic plume should pass somewhere within this area.

Health Surveillance

The symptoms of exposure to chemical agents can serve as warning signs that a chemical attack has occurred (although, with agents whose effects are delayed, these signs may become apparent after severe exposure and damaging effects have occurred). Small animals, birds, and insects may show the effects of exposure before humans, which may provide another indicator.

The critical on-scene assessments and patient examinations provided by emergency responders potentially may serve as an informal passive surveillance system. In some cases, these nationwide monitors may report potential events in a fashion timely enough to allow for rapid intervention. However, in a chemical event, surveillance is most useful for tracking exposed individuals for long-term physiological difficulties, chronic illnesses, cancers, etc.

In conducting surveillance activities, it is important not to immediately discount chemicals as the source of an unexplained syndrome. Contaminating a water or food supply with a hazardous chemical could sicken many people while prematurely eliminating chemicals as a potential cause could delay effective treatment.

Chemical Agent Diagnosis

The CDC focuses its preparedness efforts on a prioritized list of hazardous chemicals including:

- Military nerve agents.
- Sulfur and nitrogen mustards.
- Lewisite.
- Ricin.
- Saxitoxin.
- BZ.
- Hydrogen cyanide.
- Cyanogen chloride.

CDC has the capacity to monitor for chemicals mainly at the federal level. It does not advocate that state labs test potential chemical terrorism samples before shipping them to CDC. Most state public health chemical labs are not equipped to rule out the presence of a Level 4 biological agent that potentially could be present in a human sample collected from a suspected victim of a chemical attack. They also do not have the irradiators necessary to neutralize the hardiest of the biological agents if they were present.

The first 30 samples from the most contaminated (exposed) people must be sent to CDC as rapidly as possible to speed identification of the causative agent and determine whether or not a second chemical agent is involved. As many additional samples as possible should be collected and sent to CDC.

Selected Readings

Terrorism Handbook for Operational Responders, Armando Bevelacqua, Richard Stilp, Delmar, 2002, Chapter 3

Emergency Responder Guide to Terrorism, Michael Marks, Red Hat Publishing, 2002, Chapter 4

Hazardous Materials Air Monitoring and Detection Devices, Chris Hawley, Delmar, 2002, Chapters 1-12

Preparing for Terrorism, George Buck, PhD, Delmar, 2002, Chapter 4

Chemical Agents (Military) Types – Symptoms, Characteristics, and Hazards

Symbol Common Name	ERG Guide #	Agent Type	Symptoms	Physical Characteristics	Hazard
GA (tabun) GB (sarin) GD (soman) VX	153	Nerve	Pinpointing of the pupils Dimness of vision Running nose/salivation Tightness of chest Difficulty breathing Twitching or paralysis Tachycardia, vomiting Loss of consciousness Convulsions incontinence, and death	Colorless or lightly colored liquid at normal temperature G-agent slightly less volatile than water V-agents about as volatile as motor oil	Respirator dose effective within seconds to minutes—skin dose effective from minutes to hours Extremely toxic lethal agents
H HD HN	153	Vesicant (blister agent) commonly called "mustard"	Reddening of skin, blisters, eye pain, and reddening, eye damage, coughing, airway irritation, and damage	A strong odor of garlic H and HD freeze at 56 to 580 F Volatile at room temperature	Eye effects may appear in a few hours; respiratory effects and blisters in 2 to 24 hours Can be lethal in large doses

L (lewisite)	153	Vesicant	Immediate pain or irritation of skin and other symptoms similar to the H-agents	Colorless liquid with the odor of geraniums More volatile than H	Immediate pain; other symptoms in about 12 hours Can be lethal in large doses
CX (phosgene oxime)	153	Vesicant	Immediate burning weal-like skin lesions, eye and airway irritation and damage	A solid below 950 F, but vapor can result	Immediate pain—other symptoms shortly thereafter. Can be lethal in large doses.
AC (hydrogen cyanide) CK (cyanogen chloride)	117 125	Blood	Rapid breathing, dizziness, nausea, vomiting, headache, convulsions, and death Nausea, vomiting, dizziness, headache, convulsions, slow breathing, and death	Rapidly evaporating liquids	Can cause death in 6 to 8 minutes
CG (phosgene) CL (chlorine)	125 124	Choking	Eye and airway irritation, dizziness, tightness of chest, and delayed pulmonary edema	Rapidly evaporating liquid with odor of newly mown hay A gas at normal temperature	In very high doses, can result in death after several days.

Refer to Appendix C for another copy of this chart

Refer to Appendix D for more detailed information

Commonly Encountered Toxic Industrial Chemicals-Symptoms, Characteristics and Hazards

Common Name	ERG Guide #	TIC Type	Symptoms	Physical Characteristics	Hazard
Phosgene *	125	Choking	Eye and airway irritation, dizziness, tightness of chest, pulmonary edema	Rapid evaporating liquid with odor of new mown hay	In high doses, death can result
Chlorine	124	Choking	Eye and airway irritation, tightness of chest, dizziness, pulmonary edema	Becomes a gas at normal temperatures	Death can result within several days of high acute dose
Chlorine Dioxide	143	Choking	Tightness of chest, pulmonary edema, phlegm producing cough, respiratory irritation	Reddish-yellow gas, reddish brown liquid	Severe irritation to lungs, may lead to death
Ethylene Oxide	119P	Choking	Irritation to eyes and mucous membranes, central nervous system depression, pulmonary edema	Colorless gas, sweet, ether-like odor	Irritation to skin, eyes, lungs, neurological disorders
Hydrogen Chloride	125	Choking	Salivation, difficulty in swallowing, chills, overall pain, shock, pulmonary edema	Colorless gas, colorless to slightly yellow water solution, pungent, suffocating odor	Potential for circulatory system collapse
Hydrogen Cyanide *	117	Blood	High blood pressure, rapid heart rate, cherry red mucous membranes, blue tint to skin	Colorless gas, bitter almond-like odor	May be fatal if inhaled, swallowed, or absorbed through skin or mucous membranes
Propylene Oxide	127P	Choking	Skin, eyes and respiratory irritation and/or burns	Colorless liquid gas above 94 degrees F., sweet, alcohol-like odor	Inhalation and contact hazard

Common Name	ERG Guide #	TIC Type	Symptoms	Physical Characteristics	Hazard
Vinyl Acetate	129P	Blister, choking	Severe irritation to skin, eyes, and respiratory tract, blisters, dizziness, suffocation	Colorless to white liquid, sweet, pleasant odor	Inhalation and skin hazard
Ammonia	125	Choking	Respiratory spasms, severe burns to skin and mucous membranes, blindness, headache, nausea, vomiting, pulmonary edema	Colorless gas, strong irritating odor	Inhalation and skin hazard, death may occur rapidly with large acute dose
Cyanogen Chloride *	125	Blood	Upper airway irritation, nausea, headache, anxiety, agitation, weakness	Liquid, but vaporizes at 73 degrees F., pungent odor	Inhalation, large acute dose may lead to cardiovascular collapse
Methyl Isocyanate	155	Choking	Pulmonary edema, respiratory tract irritation, difficulty breathing, blindness, nausea, sweating, chills	Colorless liquid, sharp odor	Severe inhalation hazard, death will result with severe acute exposure

Appendix C

Chemical Agent Summary Charts

Phosgene (CG)

Alternate designations: Collognite, Zustaz, Green Cross, D substance		
Chemical name: Carbonyl chloride	CAS registry number: 75-44-5	RTECS number: SY5600000
Synonyms: Carbon oxychloride, chloroformyl chloride, fosgeen, fosgen, fosgene, koolstofoxychloride, phosgene		

Physical and Chemical Properties

Molecular formula: $COCl_2$
Molecular weight: 98.92

Physical state	Colorless gas
Odor	New-mown hay, grass, or green corn
Boiling point	7.5°C Freezing point -128°C Flash point None
Liquid density at 201°C	1.373 (pure CG); 1.381 (plant purity)
Vapor density (compared to air)	3.4
Vapor pressure	1,173 millimeters of mercury (mm Hg) at 20°C; 555 mm Hg at 0°C; 365 mm Hg at –10°C; (This is in the range of freon refrigerant.)
Volatility	4,300,000 mg/m^3 at 7.6°C; 2,200,000 mg/m^3 at –10°C; 528,000 mg/m^3 at –40°C
Latent heat of vaporization	59 calories per gram
Decomposition temperature	800°C
Solubility	Limited in water; decomposes immediately; completely miscible (mixes) in most organic solvents
Rate of hydrolysis	Rapid under usual field conditions; rain destroys its effectiveness; heavy vegetation, jungle, and forests cause considerable loss by hydrolysis on leafy surfaces
Hydrolysis products	Hydrochloric acid and carbon dioxide
Stability in storage	Stable in steel containers if CG is dry
Action on metals or other materials	None when CG is dry; acidic and corrosive when moist

Toxicity Data

LCt_{50}	3,200 mg-min/m^3
ICt_{50}	1,600 mg-min/m^3
Rate of detoxification	Not detoxified; cumulative
Skin and eye toxicity	Mild eye irritation
Rate of action	Delayed; immediate irritation in high concentrations; exposure to low concentration may cause no ill effects for three hours or more
Protection required	Protective mask

Other Data

Decontamination	For confined areas, aeration; not required in the field
Persistency	Short; vapor may persist for some time in low places under calm or light winds and stable atmospheric conditions (approximately 30 minutes in summer; approximately 3 hours at –20°C)
Use	Delayed-action casualty agent

Tabun (GA)

Alternate designation: Le-100	
Chemical name: Ethyl N, N-dimethylphosphoramidocyanidate	
CAS registry number: 77-81-6	RTECS number: TB4550000
Synonyms: Ethyl dimethylamidocyanophosphate, dimethylamidoethoxyphosphoryl cyanide	

Physical and Chemical Properties

Molecular formula: $C_5H_{11}N_2O_2P$ Molecular weight: 162.13

Physical state	Colorless to brown liquid
Odor	Faintly fruity but none when pure.
Boiling point	220°C to 246°C at 760 mm Hg; 120°C at 9.75 mm Hg
Melting point	-50°C Flash point 78°C
Vapor density (compared with air)	5.63
Liquid density	1.073 at 25°C
Vapor pressure	0.037 mm Hg at 20°C; 0.006 at 0°C (This is about the same as mustard.)
Volatility	858 mg/m^3 at 30°C; 328 mg/m^3 at 20°C (atmospheric pressure); 90 mg/m^3 at 0°C (This is approximately one-twentieth that of water.)
Latent heat of vaporization	79.56 calories per gram (average value between 25°C and 50°C)
Decomposition temperature	Decomposes completely at 150°C for 3-1/4 hours; GA undergoes considerable decomposition when explosively disseminated.
Solubility	Slightly soluble in water; 9.8 percent at 25°C; 7.2 percent at 20°C; readily soluble in organic solvents, such as alcohols, ethers, gasoline, oils, and fats
Rate of hydrolysis	Slow with water but fairly rapid with strong acids or alkalis; self-buffering at pH 4.5; autocatalytic below pH 4, because of presence of hydrogen cyanide (HCN); half-life, 8.5 hours at pH 7 (20°C); 7 hours at pH 4 to 5 (The rate of hydrolysis is increased by the presence of phosphate.)
Hydrolysis products	Hydrogen cyanide and other products
Stability in storage	GA is stable for several years when stored in steel containers at ordinary temperatures
Action on metals or other materials	Slightly corrosive to steel

Toxicity Data

Threshold eye effects (miosis)	2.5 mg-min/m^3 (estimated)
LCt_{50} (respiratory)	Approximately 400 mg-min/m^3 (resting)
ICt_{50} (respiratory)	Approximately 300 mg-min/m^3 (resting)
LCt_{50} (precutaneous)	Unknown; probably between 20,000 and 40,000 mg-min/m^3
LD_{50} (precutaneous)	1 to 1.5 mg/person
Rate of detoxification	Slight but definite
Skin and eye toxicity	Eyes: Very high toxicity; much greater through eyes than through skin. (Very low concentration of vapor causes pupil of eyes to constrict, resulting in difficulty in seeing in dim light.) Skin: Very toxic; decontamination of smallest drop of liquid agent is essential (penetrates skin readily).

Other Data

Protection required	Protective mask and protective clothing; clothing gives off G-agents for about 30 minutes after contact with vapor; consider this fact before unmasking; immediately remove all liquid from clothing.
Decontamination	Flush eyes with water immediately; use the M258A1, M258, or M291 skin decontaminating kit for liquid agent on the skin. Decontaminate individual equipment with the M280 individual equipment decontamination kit. Calcium hypochlorite (HTH), supertropical bleach STB), household bleach, caustic soda, dilute alkali solutions, or decontaminating solution number 2 (DS2) are effective on equipment. Use steam and ammonia or hot, soapy water in a confined area. **Note:** GA may react to form CK in bleach slurry.
Persistency	Depends upon munitions used and the weather; heavily-splashed liquid persists one to two days under average weather conditions. GA evaporates about 20 times more slowly than water. GA in water can persist about one day at 20°C and about six days at 5°C. GA persists about twice as long in sea water.

Use	Quick-acting casualty agent

Sarin (GB)

Alternate designations: Zarin

Chemical name: Isopropyl methylphosphonofluoridate CAS registry number: 107-44-8 RTECS number: TA8400000

Synonyms: Isopropyl methylfluorophosphate; isopropoxymethylphosphoryl fluoride

Physical and Chemical Properties

Molecular formula: $C_4H_{10}FO_2P$
Molecular weight: 140.10

Physical state	Colorless liquid
Odor	Almost none in pure state
Boiling point	158°C (pure); 151°C (plant grade) Freezing point -56°C Flash point Nonflammable
Liquid density	1.102 at 20°C
Vapor pressure (compared with air)	4.86
Vapor pressure	2.10 mm Hg at 20°C
Volatility	4,100 mg/m^3 at 0°C; 16,091 mg/m^3 at 20°C; 29,800 mg/m^3 at 30°C
Latent heat of vaporization	80 calories per gram at 25°C
Decomposition temperature	Complete decomposition after 1-1/2 hours at 150°C
Solubility	Soluble in all organic solvents, including alcohols, gasoline, oils, and fats; GB is miscible with water.
Rate of hydrolysis	Variable with pH; half-life 7.5 hours at pH 1.8; very rapidly hydrolyzed in alkaline solutions; half-life 5 hours at pH 9; half-life 30 hours in unbuffered solution, 47 hours at pH 6
Hydrolysis products	Hydrogen fluoride (HF) under acid conditions, isopropyl alcohol and polymers under alkaline conditions
Stability in storage	Fairly stable in steel containers at 65°C; stability improves with increasing purity
Action on metals or other materials	Slightly corrosive to steel

Toxicity Data

LCt_{50} (respiratory)	100 mg-min/m^3 (resting); 70 mg-min/m^3 (mildly active)
ICt_{50} (respiratory)	75 mg0min/m^3 (resting); 35 mg-min/m^3 (mildly active)
LC_{50} (precutaneous)	12,000 mg-min/m^3 for naked person; 15,000 mg-min/m^3 for person in ordinary combat clothing
ICt_{50} (percutaneous)	Approximately 8,000 mg-min/m^3 with ordinary clothing
Threshold eye effects (miosis)	1 mg-min/m^3
Rate of detoxification	Low; essentially cumulative
Skin and eye toxicity	Eyes: Very high toxicity; much greater through eyes than through skin (Vapor causes pupils of the eyes to constrict, and vision becomes difficult in dim light.) Skin: Lethal dose (LD) is 1.7 grams per person; liquid does not injure skin but penetrates it rapidly (Immediate decontamination of the smallest drop is essential. Vapor penetrates skin also.)
Rate of action	Very rapid; death usually results with 15 minutes after absorption of fatal dose.

Other Data

Protection required	Protective mask and protective clothing; clothing gives off G-agents for about 30 minutes after contact with vapor; consider this fact before unmasking; immediately remove all liquid from clothing.
Decontamination	Flush eyes with water immediately; use the M258A1, M258, or M291 skin decontaminating kit for liquid agent on the skin. Decontaminate individual equipment with the M280 individual equipment decontamination kit. HTH, STB, household bleach, caustic soda, dilute alkali solutions, or DS2 are effective on equipment. Use steam and ammonia or hot, soapy water in a confined area.
Persistency	Evaporates at approximately the same rate as water or kerosene and duration depends upon munitions used and the weather; GB is less persistent than GA.
Use	Quick-acting casualty agent

Soman (GD)

Alternate designations: Zoman			
Chemical name: Pinacolyl methyl phosphonofluoridate			
CAS registry number: 96-64-0	RTECS number: TA8750000		
Synonyms: 3, 3-dimethyl-n-but-2-yl methylphosphonofluoridate; methyl pinacolyl phosphonofluoridate; pinacolyl methylfuorophosphonate			
Physical and Chemical Properties			
Molecular formula: $C_7H_{16}FO_2P$ Molecular weight: 182.178			
Odor	Fruity; impurities give it the odor of camphor		
Freezing point	-42°C (generally solidifies to noncrystalline, glasslike material)		
Boiling point	198°C	Flash point	High enough not to interfere with military use
Vapor density (compared with air)	6.33		
Liquid density	1.0222 at 25°C		
Vapor pressure	0.40 mm Hg at 25°C; 531 mg/m^3 at 0°C		
Volatility	3,000 mg/m^3 at 25°C; 5,570 mg/m^3 at 30°C (This is comparable to engine oil.)		
Latent heat of vaporization	72.4 calories per gram at 25°C		
Decomposition temperature	*Stabilized* GD decomposes in 200 hours at 130°C. *Non-stabilized* GD decomposes in 4 hours at 130°C.		
Solubility	2.1 percent at 20°C and 3.4 percent at 0°C in water; soluble in sulfur mustard, gasoline, alcohols, fats, and oils		
Rate of hydrolysis	Varies with pH; complete in 5 minutes in 5-percent sodium hydroxide (NaOH) solutions; half-life at pH 6.65 and 25°C is 45 hours		
Action on metals or other materials	Slightly corrosive to metals		
Hydrolysis products	Essentially hydrogen fluoride (HF)		
Stability in storage	Less stable than GA or SB		
Toxicity Data			
Threshold eye effects (miosis)	0.16 mg-min/m^3		
LCt_{50} (respiratory)	70 mg-min/m^3 (mild activity for 10 minutes)		
ICt_{50}	Probably in GB and GA range.		
LCt_{50} (precutaneous)	Estimated to be around 10,000 mg-min/m^3		
Rate of detoxification	Low/essentially cumulative		
Skin and eye toxicity	Eyes: Very high toxicity; vapor causes pupils of eyes to contract, resulting in difficulty in seeing in dim light. Toxicity is much greater through eye than through skin. Skin: Extremely toxic by skin absorption: the estimated LD_{50} is 0.35 grams per person on bare skin (1.4 grams per person in ordinary clothing). Liquid does not injure skin but penetrates it rapidly. Immediate decontamination of the smallest drop is essential.		
Rate of action	Very rapid; death usually occurs within 15 minutes after absorption of fatal dose.		
Other Data			
Protection required	Protective mask and protective clothing; clothing gives off G-agents for about 30 minutes after contact with vapor; consider this fact before unmasking; immediately remove all liquid from clothing.		
Decontamination	Flush eyes with water immediately; use the M258A1, M258, or M291 skin decontaminating kit for liquid agent on the skin. Decontaminate individual equipment with the M280 individual equipment decontamination kit. HTH, STB, household bleach, caustic soda, dilute alkali solutions, or DS2 are effective on equipment. Use steam and ammonia or hot, soapy water in a confined area.		
Persistency	Depends upon munitions used and the weather; heavily splashed liquid persists one to two days under average weather conditions; GD evaporates about four times as slowly as water; addition of agent thickeners can greatly increase persistency.		

Use	Quick-acting casualty agent

GF

Chemical name: O-Cyclohexyl-methylfluorophosphonate or cyclohexyl methylphosphonofluoridate (CMPF)	
CAS registry number: 329-99-7	

Physical and Chemical Properties

Molecular formula: $C_7H_{14}FO_2P$
Molecular weight: 180.2

Physical state	Liquid				
Boiling point	239°C	Freezing point	-39°C	Flash point	94°C
Liquid density	1.1327				
Vapor density	6.2				
Vapor pressure	0.044 mm Hg at 20°C				
Volatility	438 mg/m^3 at 0°C; 581 mg/m^3 at 25°C				
Latent heat of vaporization	90.5 calories per gram				
Solubility	Almost entirely insoluble in water. 0.37% at 20°C				
Rate of hydrolysis	Very stable; hydrolyzes only when heated or in the presence of alkalies				
Stability in storage	Reasonably stable in steel at normal temperature				

Other Data

LD_{50} (subcutaneous)	Values are reported from 16μg/kg to 400 μg/kg (mice)
Protection required	Protective mask and protective clothing
Decontamination	Same as for GA or GB
Persistency	GF is about as persistent as GA; GF evaporates about 20 times more slowly than water; heavily-splashed liquid persists one to two days under average weather conditions.
Use	Quick-acting casualty agent

Chemical name: O-ethyl-S-(2-iisopropylaminoethyl) methyl phosphonothiolate	
CAS registry number: 50782-69-9	RTECS number: TB1090000
Synonyms: S-(2-diisopropylaminoethyl) o-ethyl methyl phosphonothiolate; ethyl-S-dimethylaminoethyl methylphosphonothiolate	

Physical and Chemical Properties

Molecular formula: $C_7H_{16}FO_2P$
Molecular weight: 182.178

Physical state	Amber-colored oily liquid
Odor	None
Boiling point	298°C (calculated) decomposes Flash point 159°C
Freezing point	Below –51°C because of dissolved impurities; -39°C calculated
Vapor density (compared with air)	9.2
Liquid density	1.008 g/cc at 20°C
Vapor pressure	0.0007 mm Hg at 20°C
Volatility	10.5 mg/m^3 at 25°C (This is about 2,000 times less volatile than GB.)
Latent heat of vaporization	78.2 calories per gram at 25°C
Decomposition temperature	Half-life: 36 hours at 159°C; 1.6 hours at 200°C; 4 minutes at 250°C; 36 seconds at 295°C
Solubility	Miscible with water below 9.4°C; slightly soluble in water at room temperature; soluble in organic solvents
Rate of hydrolysis	Half-life at 25°C: 100 days at pH 2 or 3; 16 minutes at pH 13; 1.3 minutes at pH 14
Hydrolysis products	Toxic hydrolysis products form at pH 7 to 10: Diethyl methylphosphonate, 2-diisopropylamineothyl mercaptan, ethyl hydrogen methylphosphonate, bis (ethylmethylphosphonic) anhydride, bis S-(2-diisopropyl-0-aminoethyl) methylphosphonodithioate
Stability in storage	Relatively stable at room temperature; unstabilized VX of 95-percent purity decomposes at a rate of 5 percent a month at 71°C
Action on metals or other materials	Negligible on brass, steel, and aluminum

Toxicity Data

Threshold eye effects (miosis)	0.04 mg/m^3
LCt_{50} (respiratory)	100 mg-min/m^3 (resting); 30 mg-min/m^3 (mild activity)
ICt_{50} (respiratory)	50 mg-min/m^3 (resting); 24 mg-min/m^3 (mild activity)
LCt_{50} (precutaneous)	6 to 360 mg-min/m^3 (bare skin); 6 to 3,600 mg-min/m^3 (clothed)
LD_{50} (precutaneous)	10 mg per person (bare skin)
Rate of detoxification	Low, essentially cumulative
Skin and eye toxicity	Extremely toxic by skin and eye absorption; about 100 times as potent as GB: Liquid does not injure the skin or eye but penetrates rapidly. Immediate decontamination of the smallest drop is essential.
Rate of action	Very rapid; death usually occurs within 15 minutes after absorption of fatal dosage.

Other Data

Protection required	Protective mask and protective clothing
Decontamination	HTH and STB slurries; household bleach; DS2 solution; hot, soapy water: Decontaminate liquid agent on the skin with the M258A1, M258, or M291 skin decontaminating kit. Decontaminate individual equipment with the M280 individual equipment decontamination kit.
Persistency	Depends upon munitions used and the weather; heavily-splashed liquid persists for long periods under average weather conditions. In very cold weather, VX can persist for months. VX is approximately 1,500 times slower in evaporating than GB.
Use	Delayed casualty

Hydrogen Cyanide (AC)

Alternate designations: Cyclone B; Zyklon B		
Chemical name: Hydrogen cyanide	CAS registry number: 74-90-8	RTECS number: MW6825000
Synonyms: Hydrocyanic acid		

Physical and Chemical Properties

Molecular formula: HCN
Molecular weight: 27.03

Physical state	Colorless liquid that quickly evaporates
Odor	Bitter almonds or peach kernels
Freezing point	-13.3°C Boiling point 25.7°C
Flash point	-18°C; Agent ignites 50 percent of the time when disseminated from an artillery shell.
Vapor density (compared with air)	1.007 at 25.7°C; 0.990 at 20°C; 0.978 at 0°C; 0.93 at –17.8°C
Liquid density	0.687 g/cc at 20°C; 0.716 at 0°C
Vapor pressure	612 mm Hg at 20°C; 265 mm Hg at 0°C
Volatility	1,080,000 mg/m^3 at 25°C; 441,000 mg/m^3 at 0°C
Latent heat of vaporization	233 calories per gram
Decomposition temperature	Above 65.5°C; forms explosive polymer on standing. Stabilized material can be stored up to 65°C.
Solubility	Highly soluble and stable in water and alcohol; soluble in ether, glycerin, chloroform, and benzene
Rate of hydrolysis	Low under field conditions
Hydrolysis products	Ammonia; Formic acid (HCOOH), and amorphous brown solids
Stability in storage	Unstable except when very pure; forms explosive polymer on long standing; will stabilize with addition of small amounts of phosphoric acid or sulfur dioxide (See decomposition temperature)
Action on metals or other materials	Little or none

Toxicity Data

LCt_{50}	Varies widely with concentration because of the rather higher rate at which the body detoxifies AC; at 200 mg/m3 concentration, the LCt_{50} is approximately 2,000 mg-min/m^3, whereas at 150 mg/m^3 the LCt_{50} is approximately 4,500 mg-min/m^3.
ICt_{50}	Varies with the concentration
Rate of detoxification	Rapid; 0/017 mg/kg/min
Skin and eye toxicity	Moderate
Rate of action	Very rapid; incapacitation occurs within 1 or 2 minutes of exposure to an incapacitating or lethal dose. Death can occur within 15 minutes after receiving a lethal dose.

Other Data

Protection required	Protective mask: liquid AC can penetrate skin but, because AC has a high LCt_{50} and because liquid AC is not likely to be encountered in the field, protective clothing is required only in unusual situations.
Decontamination	None required under field conditions
Persistency	Short; the agent is highly volatile, and in the gaseous state it dissipates quickly in the air.
Use	Quick-acting casualty agent suitable for surprise attack

Cyanogen Chloride (CK)

Alternate designations: Mauginite; CC; Klortsian		
Chemical name: Cyanogen chloride	CAS registry number: 506-77-4	RTECS number: GT2275000
Synonyms: Chlorcyan; chlorine cyanide; chlorocyanogen		

Physical and Chemical Properties

Molecular formula: CNCI
Molecular weight: 61.48

Physical state	Colorless liquid that evaporates quickly
Odor	Pungent, biting; but will go unnoticed because of its intense irritating and tearing properties
Freezing point	-6.9^{o}C Boiling point 12.8^{o}C Flash point None
Liquid density	1.18 at 20^{o}C
Vapor density (compared to air)	2.1
Vapor pressure	1,000 mg Hg at 25^{o}C
Volatility	6,132,000 mg/m^3 at 25^{o}C; 2,600,000 mg/m^3 at 12.8^{o}C
Latent heat of vaporization	103 calories per gram (This is sufficiently high to provide a satisfactory pancaking effect.)
Decomposition temperature	Above 100^{o}C
Solubility	Slightly soluble in water; dissolves readily in alcohol, carbon disulfide, acetone, benzene, carbon tetrachloride, chloropicrin, HD, and AC
Rate of hydrolysis	Very low
Hydrolysis products	Hydrogen chloride and cyanic acid (CNOH)
Stability in storage	Stable at 65^{o}C for 30 days; will polymerize to form the solid cyanuric chloride which is corrosive. Impurities promote polymerization and *may explode*.
Action on metals or other materials	None if CK is dry; attacks may common metals when stored unstabilized (See stability)

Toxicity Data

Median concentration detectable (by tearing effect)	12 mg/m^3
LCt_{50}	11,000 mg-min/m^3
ICt_{50}	7,000 mg-min/m^3
Rate of detoxification	0.02 to 0.1 mg/kg/min
Skin and eye toxicity	Too low to be of military importance; highly irritating to eyes, upper respiratory tract, and lungs; CK can cause dryland drowning
Rate of action	Immediate, intense irritation: the systemic effect of CK is believed to arise from its conversion to AC in the body. In general, CK may be considered a rapid-acting chemical agent.

Other Data

Protection required	Protective mask: CK will break or penetrate a protective mask canister or filter element more readily than most other agents. A very high concentration may overpower the filter; high dosages will break down its protective ability.
Decontamination	None required under field conditions
Persistency	Short; vapor may persist in jungle and forest for some time under suitable weather conditions.
Use	Quick-acting casualty agent used for degradation of canisters or filter elements in protective mask

Distilled Mustard (HD)

Alternate designations: HS; Kampstoff "Lost"; mustard gas; S-Lost; Schewefel-lost; sulfur mustard; Y; Yellow Cross liquid; Yperite

Chemical name: Bis-(2-chloroethyl) sulfide   CAS registry number: 505-60-2   RTECS number: WQ0900000

Synonyms: 2-2'-dichloroethyl sulfide; 1,1'-thiobis(2-chloroethane)

Physical and Chemical Properties

Molecular formula: $C_4H_8Cl_2S$ Molecular weight: 159.08

Physical state	Oily, colorless to amber liquid
Odor	Like garlic or horseradish
Boiling point	227.8°C (216°C calculated; decomposes) Freezing point 14.45°C
Flash point	105°C; low enough to cause occasional ignition if explosive charges in the shell are too great
Solid density	1.37 g/cm^3 at 0°C
Liquid density	1.27 g/cm^3 at 20°C
Vapor density (compared to air)	5.4
Vapor pressure	0.072 mm Hg at 20°C
Volatility	75 mg/m^3 at 0°C (solid); 610 mg/m^3 at 20°C (liquid); 2,860 mg/m^3 at 40°C (liquid)
Latent heat of vaporization	94 calories per gram (This property is not of great importance in an agent of low volatility, as the sustained vapor concentration is essentially a function of the surrounding temperature.)
Decomposition temperature	149°C to 177°C
Solubility	Barely soluble in water (less than 1 percent); freely soluble in fats and oils, gasoline, kerosene, acetone, carbon tetrachloride, alcohol, PS, and FM. Miscible with DP, L, ED, PD, and the organophosphorus nerve agents
Rate of hydrolysis	Half-life is 8.5 minutes in distilled water at 25°C and 60 minutes in salt water at 25°C; mustard on or under water undergoes hydrolysis only if dissolved. It is only slightly soluble in water; as a result mustard may persist in water for long periods. Alkalinity and higher temperatures increase the rate of hydrolysis.
Hydrolysis products	Hydrogen chloride and thiodiglycol
Stability in storage	Stable in steel or aluminum containers
Action on metals or other materials	Very little when pure

Toxicity Data

LD_{50}	7 grams per person (estimated)
LCt_{50} (respiratory)	1,500 mg-min/m^3
ICt_{50} (respiratory)	150 mg-min/m^3
LCt_{50} (percutaneous)	10,000 mg-min/m^3
ICt_{50} (percutaneous)	2,000 mg-min/m^3 or less; wet skin absorbs more mustard than does dry skin. For this reason, HD exerts a casualty effect at lower concentrations in hot, humid weather, because the body is then moist with perspiration. The dosage given above for skin absorption applies to temperatures of approximately 21°C to 27°C, as the body would not be perspiring excessively at these temperatures. Above 27°C perspiration causes increased skin absorption. The incapacitating dose requirement drops rapidly as perspiration increases; at 32°C 1,000 mg-min/m^3 could be incapacitating.
Eye injury (Ect_{50})	100 to 200 mg-min/m^3
Rate of detoxification	Very low; even very small, repeated exposures of HD are cumulative in their effects or more than cumulative owing to sensitization. This has been shown in the postwar case histories of workers in mustard-filling plants. Exposure to vapors from spilled HD causes minimum symptoms, such as "red eye." Repeated exposure to vapor causes 100-percent disability by irritating the lungs and causing a chronic cough and pain in the chest.
Skin and eye toxicity	Eyes are very susceptible to low concentrations. Incapacitating effects by skin absorption require higher concentrations.
Rate of action	Delayed; usually 4 to 6 hours until first symptoms appear. Latent periods of up to 24 hours

have been observed, however, and in rare cases of up to 12 days.

Distilled Mustard (HD) Continued

Other Data	
Protection required	Protective mask and permeable protective clothing for vapor and small droplets; impermeable clothing for protection against large droplets, splashes, and smears
Decontamination	STB, fire, or DS2; decontaminate liquid agent on the skin with the M258A1, M258, or M291 skin decontaminating kit. Decontaminate individual equipment with the M280 individual equipment decontamination kit.
Persistency	Depends upon the amount of contamination by liquid, the munition used, the nature of the terrain and the soil, and the weather conditions; heavily-splashed liquid persists one to two days or more in concentrations that produce casualties of military significance under average weather conditions, and a week to months under very cold conditions. HD on soil remains vesicant for about two weeks. An incident in which mustard leaked and soaked into soil caused blisters after three years. HD evaporates about five times more slowly than GB. Persistency in running water is only a few days, while persistency in stagnant water can be several months. HD is about twice as persistent in sea water.
Use	Delayed-action casualty agent

Nitrogen Mustard (HN-1)

Alternate designations: Ethyl S; NH-Lost; NOR nitrogen mustard; NSC 10873		
Chemical name: Bis-(2-chloroethyl)ethylamine	CAS registry number: 538-07-8	RTECS number: YE1225000
Synonyms: Ethylbis(2-chloroethyl)amine		

Physical and Chemical Properties	
Molecular formula: $C_6H_{13}Cl_2N$ Molecular weight: 170.08	
Physical state	Oily, colorless to pale yellow liquid
Odor	Faint, fishy, or musty
Freezing point	-34°C; Flash point: High enough not to interfere with military use of the agent
Boiling point	194°C calculated; at atmospheric pressure, HN-1 decomposes below boiling point.
Vapor density (compared to air)	5.9
Liquid density	1.09 at 25°C
Vapor pressure	0.24 mm Hg at 25°C
Volatility	127 mg/m^3 at –10°C; 308 mg/m^3 at 0°C; 1,520 mg/m^3 at 20°C; 3,100 mg/m^3 at 30°C; HN-1 closely parallels HD in the variation of volatility with temperatures and is of little value in producing a vapor hazard when weather is cold.
Latent heat of vaporization	77 calories per gram
Decomposition temperature	Decomposes before boiling point is reached.
Solubility	Sparingly soluble in water; freely soluble in acetone and other organic solvents
Rate of hydrolysis	Slow because of low solubility in water; less readily hydrolyzed than mustard
Hydrolysis products	Hydrolxyl derivatives and condensation products (All intermediate hydrolysis products are toxic.)
Stability in storage	Adequate for use in munitions; polymerizes slowly
Action on metals or other materials	Slight corrosion of steel at 65°C
Toxicity Data	
LCt_{50} (respiratory)	1,500 mg-min/m^3
LCt_{50} (percutaneous)	20,000 mg/min/m^3
ICt_{50} (percutaneous)	9,000 mg-min/m^3
ICt_{50} (eye injury)	200 mg-min/m^3
Rate of detoxification	Not detoxified; cumulative
Skin and eye toxicity	Eyes are very susceptible to low concentration; incapacitating effects by skin absorption require higher concentrations.
Rate of action	Delayed; 12 hours or longer
Other Data	
Protection required	Protective mask and permeable protective clothing for vapor and small droplets; impermeable clothing for protection against large droplets, splashes, and smears
Decontamination	HTH, STB, household bleach, fire, or DS2; decontaminate liquid agent on the skin with the M258A1, M258, or M291 skin decontaminating kit. Decontaminate individual equipment with the M280 individual equipment decontamination kit.
Persistency	Depends on munitions used and the weather; somewhat shorter than duration of effectiveness for HD, the heavily splashed liquid of which persists one to two days under average weather conditions and a week or more under very cold conditions
Use	Delayed-action casualty agent

Nitrogen Mustard (HN-2)

Alternate designations: Dichloren; N-methyl-Lost; mustine; nitrogen mustard; NSC 762; S	
Chemical name: Bis-(2-chloroethyl)methylamine	CAS registry number: 51-75-2 RTECS number: IA17500000
Synonyms: 2,2'd-chloro-N-methyldiethylamine; chloramines; N,N-bis(2-chloroethyl)methylamine	
Physical and Chemical Properties	
Molecular formula: $C_5H_{11}C_{l2}N$ Molecular weight: 156.07	
Physical state	Dark liquid
Odor	Fruity in high concentrations. Like soft soap in low concentrations
Freezing point	-65^{o}C to –60^{o}C Flash point High enough not to interfere with military use
Boiling point	75^{o}C at 15 mm Hg. At atmospheric pressure HN-2 decomposes below its boiling point.
Liquid density	1.15 at 20^{o}C
Vapor density (compared to air)	5.4
Vapor pressure	0.29 mm Hg at 20^{o}C; 1.25 mm Hg at 40^{o}C
Volatility	3,580 mg/m^3 at 25^{o}C; 5,100 mg/m^3 at 30^{o}C; 10,000 mg/m^3 at 40^{o}C
Latent heat of vaporization	78.8 calories per gram
Decomposition temperature	Decomposes before boiling point is reached; instability of HN-2 is associated with its tendency to polymerize or condense. The reactions involved could generate enough heat to cause at explosion.
Solubility	Soluble in acetone and organic solvents; sparingly soluble in water
Rate of hydrolysis	Slow except where alkali is present; dimerizes rapidly in water.
Hydrolysis products	Complex condensates or polymers
Stability in storage	Not stable
Action on metals or other materials	None
Toxicity Data	
LCt_{50} (respiratory)	3,000 mg/min/m^3
ICt_{50} (eye injury)	100 mg-min/m^3
ICt_{50} (percutaneous)	Somewhere between the values given for HN-1 and HN-3
Rate of detoxification	Not detoxified
Skin and eye toxicity	HN-2 has the greatest blistering power of the nitrogen mustards in vapor form, but it is intermediate as a liquid blistering agent. It produces toxic eye effects more rapidly than does HD.
Rate of action	Skin effects delayed: 12 hours or longer
Other Data	
Physiological action	Same as for HD
Protection required	See distilled mustard
Decontamination	Same as for HD
Persistency	Same as for HD based on evaporation; however, less than HD because of instability (See distilled mustard)
Use	Delayed-action casualty agent

Nitrogen Mustard (HN-3)

Alternate designations: Nitrogen mustard-3; TO

Chemical name: Tris(2-chloroethyl)amine | CAS registry number: 555-77-1 | RTECS number: YE265000

Synonyms: 2,2', 2"-trichlorotriethylamine; tri(2-chloroethyl)amine

Physical and Chemical Properties

Molecular formula: $C_6H_{12}Cl_3N$
Molecular weight: 204.54

Physical state	Oily liquid
Odor	None when pure.
Freezing point	-3.7^{o}C Flash point High enough not to interfere with military use
Boiling point	256^{o}C calculated; at atmospheric pressure, HN-3 decomposes below boiling point.
Liquid density	1.24 at 25^{o}C
Vapor density (compared to air)	7.1
Vapor pressure	0.0109 mm Hg at 25^{o}C
Volatility	13 mg/m^3 at 0^{o}C; 121 mg/m^3 at 25^{o}C; 180 mg/m^3 at 30^{o}C; 390 mg/m^3 at 40^{o}C: with no greater vapor toxicity than HD, HN-3 has a volatility too low to yield an effective vapor concentration even under tropical conditions.
Latent heat of vaporization	74 calories per gram
Decomposition temperature	Decomposes before boiling point is reached
Solubility	Soluble in sulfur mustards and chloropicrin; insoluble in water, being less soluble than sulfur mustard; soluble in ether, benzene, and acetone
Rate of hydrolysis	Very slow because of low solubility in water
Hydrolysis products	Hydrochloric acid and triethanolamine, $N(CH_2CH_2OH)_3$, in dilute solutions; dimer formation in higher concentrations
Stability in storage	Stable enough for use as a bomb filling even under tropical conditions; however, the agent darkens and deposits a crystalline solid in storage.
Action on metals or other materials	None if HN-3 is dry

Toxicity Data

LD_{50} (percutaneous)	0.7 gram per person (estimated)
LCt_{50} (respiratory)	1,500 mg-min/m^3
LCt_{50} (percutaneous)	10,000 mg-min/m^3
ICt_{50} (eye injury)	200 mg-min/m^3
ICt_{50} (percutaneous)	2,500 mg-min/m3; this information is based on estimates and indicates that HN-3 closely approaches HD in vapor toxicity and that it is the most toxic of the nitrogen mustards
Rate of detoxification	Not detoxified; cumulative
Rate of action	Most symptoms are delayed four to six hours (same as for HD). In some cases eye irritation, tearing, and sensitivity to light (photophobia) develop immediately.

Other Data

Protection required	Protective mask and permeable protective clothing for vapor and small droplets; impermeable clothing for protection against large droplets, splashes, and smears
Decontamination	STB, fire, or DS2; decontaminate liquid agent on the skin with the M258A1, M258, or M291 skin decontaminating kit. Decontaminate individual equipment with the M280 individual equipment decontamination kit.
Persistency	Considerably longer than for HD (see HD)
Use	Delayed-action casualty agent

Lewisite (L)

Alternate designation: Lyvizit	
Chemical name: Dichloro-(2-chlorovinyl)arsine CAS registry number: 541-25-3 RTECS number: CH2975000	
Synonyms: Chlorovinylarsine dichloride; 2-chlorovinyldichloroarsine	
Physical and Chemical Properties	
Molecular formula: $C_2H_2AsCl_3$ Molecular weight: 207.35	
Physical state	Colorless to brownish liquid
Odor	Like geraniums; very little odor when pure
Freezing point	18°C to 0.1°C (depending on purity and isomers present) Boiling point 190°C Flash point None
Vapor density (compared to air)	7.1
Liquid density	1.89 at 20°C (much heavier than mustard)
Vapor pressure	0.087 mm Hg at 0°C; 0.394 mm Hg at 20°C (higher than HD at room temperature)
Volatility	1,060 mg/m^3 at 0°C; 4,480 mg/m^3 at 20°C; 8,620 mg/m^3 at 30°C
Latent heat of vaporization	58 calories per gram from 0°C to 190°C
Decomposition temperature	Above 100°C
Solubility	Soluble in organic solvents and oils; insoluble in water and dilute mineral acids: because of its good miscibility with other chemical warfare agents, L is suitable for the preparation of tactical mixtures.
Rate of hydrolysis	Rapid for vapor and dissolved lewisite; Low solubility in water limits the hydrolysis
Hydrolysis products	Hydrolchloric acid and chlorovinyl arsenous oxide, a vesicant; the latter is a nonvolatile solid that is not readily washed away by rains. Strong alkalies destroy these blister-forming properties.
Stability in storage	Stable in steel or glass container
Action on metals or other materials	None if L is dry
Toxicity Data	
LD_{50}	30 mg/kg
LCt_{50} (respiratory)	1,400 mg-min/m^3: the intense irritation to the respiratory tract usually causes exposed personnel to mask immediately to avoid the vapor.
LCt_{50} (percutaneous)	100,000 mg-min/m3; when the humidity is high, L hydrolyzes so rapidly that it is difficult to maintain a vapor concentration sufficient to blister bare skin. The high vapor pressure and short duration of effectiveness of L further increase this difficulty.
ICt_{50} (percutaneous)	Over 1,500 mg-min/m3. Lewisite irritates the eyes and skin and gives warning of its presence.
Skin and eye toxicity	Even limited concentrations of L vapor (below 300 mg-min/m^3) cause extreme irritation of the eyes. Burning, pain, sensitivity to light, tearing, and swelling of the eyelids result. An exposure of 1,500 mg-min/m^3 produces severe and probably permanent corneal damage to the eyes. Liquids cause severe damage to the eye. L has about the same blistering action on the skin as HD, even though the lethal dosage for L is much higher.
Rate of detoxification	The body does not detoxify lewisite.
Rate of action	Rapid; the body absorbs L more rapidly through the skin than it absorbs the nitrogen mustards.
Other Data	
Protection required	Protective mask and permeable protective clothing for vapor and small droplets; impermeable protective clothing for protection against large droplets, splashes, and smears
Decontamination	HTH, STB, household bleach, DS2, or caustic soda; decontaminate liquid agent on the skin with the M258A1, M258, or M291 skin decontaminating kit. Decontaminate individual equipment with the M280 individual equipment decontamination kit.
Persistency	Somewhat shorter than for HD; very short duration under humid conditions
Use	Moderately delayed-action casualty agent

Phosgene Oxime (CX)

Alternate designation: Fosgen Oksim	
Chemical name: Dichloroformoxime	
Synonyms: Phosgene oxime	
Physical and Chemical Properties	
Molecular formula: $CHCl_2NO$	
Molecular weight: 113.9	
Physical state	Liquid above 39°C; solid below 35°C
Odor	Intense, penetrating, disagreeable, and violently irritating
Freezing/Melting point	35°C to 40°C Flash point Not available
Boiling point	129°C (with decomposition)
Liquid density	Not available
Vapor density (compared to air)	3.9
Vapor pressure	11.2 mm Hg for solid at 25°C; 13 mm Hg for liquid at 40°C
Volatility	1,00 mg/m^3 at 20°C; 76,000 mg/m^3 at 40°C
Latent heat of vaporization	101 calories per gram at 40°C
Decomposition temperature	Below 128°C
Solubility	Dissolves slowly but completely in water; very soluble in organic solvents
Rate of hydrolysis	Slow in water at pH 7 and room temperature; 5 percent in six days at ambient temperature; not hydrolyzed by dilute acids; reacts violently in basic solutions
Hydrolysis products	Carbon dioxide, hydrogen chloride, and hydroxylamine
Stability in storage	Extremely unstable in presence of traces of metals or other impurities: even traces of iron chloride may cause explosive decomposition. Pure material is stable only for one to two months. It may be stabilized by nitromethane, chloropicrin, glycine, ethyl acetate, or ether—but only in glass vessels below 20ÉC. Apparently, it is most stable in aromatic solvents.
Action on metals or other materials	Corrosive to most metals (See preceding paragraph)
Toxicity Data	
LCt_{50}	3,200 mg-min/m^3 (estimated)
ICt_{50}	Unknown; the lowest irritant concentration after a ten-second exposure is 1 mg/m^3. The effects of the agent become unbearable after one minute at 3 mg/m^3
Skin and eye toxicity	Violently irritating to eyes: very low concentrations cause copious tearing, inflammation, and temporary blindness. Liquid on skin is corrosive.
Rate of detoxification	Not known
Rate of action	Rapid
Other Data	
Protection required	A properly fitting protective mask protects the respiratory system. A complete set of protective clothing will protect the remainder of the body.
Decontamination	Use large amounts of water or DS2 on equipment. Because of the rapid reaction of CX with the skin, decontamination will not be entirely effective after pain occurs. Nevertheless, decontaminate as rapidly as possible by flushing the area with large amounts of water to remove any agent that has not reacted with the skin.
Persistency	About two hours in soil; relatively non-persistent on surfaces and in water
Use	Rapid-acting casualty agent